



Specification

METHOD FOR PRODUCING A FIBER COMPOSITE COMPONENT, AND APPARATUS  
FOR PRODUCING SUCH A COMPONENT

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The invention relates to a method for producing a fiber composite component having at least one intersection or node point. An apparatus for producing a component, comprising fiber composite material, including lower and upper dies of a pressing tool and optionally a heat source, by means of which source the fiber composite material can be heated during its subjection to pressure in the pressing tool.

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In high-temperature furnace and factory construction, in the hardening and sintering industry, bases of preferably gridlike structure that are resistant to high temperature and that must have high mechanical strength are used. CFC (carbon fiber reinforced carbon) grates have proven themselves for this purpose. In the prior art, they are put together from strips or are made from plate material, for instance by waterjet cutting. Grates of metal high-temperature alloys made by casting are also known.

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When CFC strip material is used, it must be cut out in the region of the intersection points in order to assure that the bearing area of the grid extends in the same plane, or in other words that no thickening of material is present in the region of the intersection points.

Such work is complicated and thus expensive. The same is true for the case where grids are cut out of plate material, since in this case the material waste is undesirably high. The known grates comprising CFC materials consequently have disadvantages with regard to machining and production costs and with regard to joining in the case of plugged-together systems.

The disadvantages in these regards may possibly not arise with grates made by casting. However, such grates have an undesirably high thermal capacity and can warp in the presence of frequently changing temperatures. The usage temperatures are also limited. A tendency to creepage and major wall thicknesses can be named as further disadvantages.

From International Patent Disclosure WO92/11126, a textile composite material with reinforcing fibers is known in which the intersection or node points have a greater thickness than the adjoining regions.

In order to produce a grid made of reinforcing fibers that has different elasticity in different directions, according to WO92/11126, first fiber bundles have a number of fibers that differs from second fiber bundles. After the production of the grid, the cross section of the grid in the region of the node points can be adapted to that of the adjoining regions by the exertion of pressure.

The object of the present invention is to refine a method and an apparatus of the type defined at the outset in such a

way that a nonwarping, lightweight, easily manipulated component with at least one intersection point, in particular a grate, can be produced that has shape stability and can be produced economically.

5 In terms of the method, this object is essentially attained in that an integral component (preform) of the same or substantially the same material thickness and/or the same or substantially the same fiber volume content at the at least one intersection point and adjoining portions of the component is placed in a mold which predetermines or substantially predetermines its final geometry, and before or after being placed in the mold is provided with a monomer such as resin or a polymer and then cured. In particular, it is provided that the preform, for curing, is subjected to a heat treatment. A blank thus produced can then pyrolyzed. The curing of the fiber preform takes place in the mold, and the pyrolyzing and carbonizing and/or graphitizing are done place outside the mold.

In particular, a fiber preform is used that as its fibers has roving strands and/or fibers or slivers comprising natural, glass, aramide, polymer, carbon and/or ceramic fibers. As the resin itself, a phenol-derived resin, such as resol in particular, is especially used.

Although preferably the preform is impregnated or saturated with resin, and a phenol-derived resin is to be

emphasized, the possibility also exists that along with the reinforcing fibers, polymer fibers that form the matrices, such as PEEK fibers, PPS fibers, PA fibers, PE fibers or PP fibers are used.

5 It should also be pointed out that the teaching of the invention is also intended for producing components that comprise fiber reinforced plastic material. The preform used can be subjected to cold or hot curing. Corresponding components comprising fiber-reinforced plastic can furthermore  
10 be at least carbonized but also carbonized and graphitized, making components of fiber reinforced carbon or graphite available. As preferred reinforcing fibers, ceramic fibers such as SiC fibers or carbon fibers can be named.

15 In other words, with the teaching of the invention both fiber-reinforced plastic components and fiber reinforced carbon components can be made, which are distinguished in particular by their high-temperature resistance.

The fiber preforms are produced in particular by tailored fiber placement (TFP) technology. In this, fiber material  
20 unwound from a spool is laid and joined with sewing thread in such a way that a preform of desired geometry is available; different material thicknesses can be attained by stitching repeated layers on top of one another.

Preforms made by TFP technology and having intersection points such as nodes have the advantage that the fiber volume

By the production methods known per se, a preform is made that can have a grid shape; as a result of the laying of the reinforcing fibers and stitching them at the intersection points, a material thickness that is equivalent to the thickness between the intersection points is attainable. A thus-produced preform is then impregnated with resin and placed in a die of a pressing tool, which die in turn has mold voids that correspond to the geometry of the preform and thus of the final form. The voids themselves are defined by flexible

elements, so that regardless of the shrinkage that occurs in curing, a release of the cured preform (blank) is possible by exerting pressure on the flexible elements. During the curing, a further die, which corresponds to the negative shape of the voids that receive the preform, acts on the preform. This is preferably a die comprising metal, such as steel.

The thus-cured blank is then carbonized at a temperature  $T_1$  where  $500^{\circ}\text{C} \leq T_1 \leq 1450^{\circ}\text{C}$ , and in particular  $900^{\circ}\text{C} \leq T_1 \leq 1200^{\circ}\text{C}$ , or graphitized at a temperature  $T_2$  where  $1500^{\circ}\text{C} \leq T_2 \leq 3000^{\circ}\text{C}$ , and in particular  $1800^{\circ}\text{C} \leq T_2 \leq 2500^{\circ}\text{C}$ .

An apparatus for producing a component, comprising fiber composite material, of the type defined at the outset is distinguished in particular in that one of the dies of the pressing tool has mold voids for receiving fiber composite material that are defined by flexible elements that follow a shrinkage of the fiber composite material upon heating, and that the other die has a geometry that is adapted to the voids. In particular, it is provided that the voids are formed by intersecting receptacles for the fiber composite material that are defined by the flexible elements, each of which has a block-like geometry. In this case, the further die engaging the voids or aligned with them has a gridlike geometry. The die itself is preferably of metal, such as steel.

Further details, advantages and characteristics of the invention will become apparent not only from the claims and the

characteristics learned from them - in isolation and/or in combination - but also from the ensuing description of preferred exemplary embodiments seen in the drawing.

Shown are:

Fig. 1, a gridlike fiber preform;

Fig. 2, a grid produced from the fiber preform of Fig. 1;  
and

Fig. 3, elements of a pressing tool for producing a blank from the fiber preform of Fig. 1.

In the exemplary embodiments described below, a fiber composite component in the form of a grid 10 will be explained, but this is not intended to limit the teaching of the invention in any way. On the contrary, this teaching also extends to all instances of the application of a fiber composite component to be made by the method of the invention that is intended in particular for use in high-temperature furnace and factory construction, in the hardening and sintering industry, as column bases for chemical reactors, as core material for sandwich structures, or as batch carrier systems.

In order to make a corresponding component 10 available that even at its intersection points 12 has a thickness that does not differ from that in the adjoining region, that is, crosspieces 14, 16, a fiber preform or so-called preform 18 is used, which can be made by the tailored fiber placement (TFP) technology or a corresponding method. To that end, reinforcing

fibers such as roving strands and/or fibers or slivers comprising natural, glass, aramide, polymer, carbon and/or ceramic fibers are laid and stitched in accordance with the geometry desired; at the intersection points 12, the fibers are laid in such a way that a thickness or cross section results that corresponds to that of the adjoining portions 14, 16.

It is also possible to produce the preforms by tow placement methods with appropriate final pressing, or by the resin transfer molding (RTM) technique.

Regardless of the method employed, the preform 18 has a substantially constant thickness over its entire area. The thus-produced preform 18 is then placed in a lower die 20 of a pressing tool, specifically in voids 22, which are formed by intersecting receptacles and which have a course of geometry that corresponds to that of the preform 18. The receptacles 22 are defined by flexible elements 26, which have a blocklike geometry. To that end, the flexible blocklike elements 26 originate at a metal base plate 24, and are disposed relative to one another and spaced apart from one another in such a way that a void geometry results that corresponds to the preform 18 and thus approximately to the final geometry of the fiber composite component 10.

Before the preform 18 is placed in the lower die 20, the preform 18 is saturated or impregnated with resin, in particular a phenol-derived resin. Alternatively or



additionally, along with the reinforcing fibers, polymer fibers can be used that form the matrices or in other words perform the function of the resin. Thermoplastic fibers such as PEEK fibers, PPS fibers, PA fibers, PE fibers or PP fibers can be considered as the polymer fibers.

Once the preform 18 has been placed in the lower die 20, then because of the geometry of the exemplary embodiment, an upper die 28 corresponding to a grid is aligned with the receptacles 22, and then the lower die 20 and upper die 28 are closed, in order to exert the requisite pressure on the preform 18. Simultaneously a heat treatment is performed, such that curing of the resin-impregnated preform 18 or melting of the thermoplastic fibers occurs. Since in the curing shrinkage of the preform is possible, the crosspieces 14, 16 surround the elements 26 of the lower die 20 in clamping fashion. However, since the elements 26 are flexible, removing the cured preform 18 or blank merely requires compressing these elements to the requisite extent in order to remove the blank from the lower die 20.

Next, to the desired extent, carbonizing or graphitization of the blank is done in order to obtain a fiber composite component 10 as shown in Fig. 2. Thus as noted, each intersection point 12 has a thickness that corresponds to that of the crosspieces 14, 16. This in turn means that the grid 10 defines an area with a flat surface, so that a desired use, in

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particular as a base, for instance, is possible.